CLAIMS

We claim:

1. A method for increasing the efficiency of a system comprising a fuel reformer coupled to a fuel cell, the method comprising the steps of:

using heat generated by the fuel cell to make a pressurized air/steam mixture, optionally in admixture with water, by direct evaporation of cooling water from the fuel cell into pressurized air;

injecting the pressurized air/steam mixture as an oxidant into a fuel burner;

producing a steam-containing exhaust having an expansion potential from the fuel burner;

driving an expander using the expansion potential of the steam-containing exhaust; and,

recovering mechanical energy from the expander.

2. The method of Claim 1, further comprising the step of preheating the air/steam mixture in the steam-containing exhaust of the fuel burner before injection into the burner.

3. The method of Claim 1, further comprising the step of using the air/steam mixture as a humidified oxidant of a fuel cell.

4. The method of Claim 1, further comprising the step of injecting additional water into the air/steam mixture.

5. The method of Claim 4, wherein the step of injecting additional water occurs after the mixture has emerged from the fuel cell.

6. The method of Claim 1, wherein the steam-containing exhaust is a heat source for a fuel reformer.

7. The method of Claim 6, wherein the fuel reformer conducts at least one reaction selected from the group consisting of steam reforming, partial oxidation and autothermal reforming.

8. The method of Claim 7, wherein the fuel reformer reaction comprises steam reforming.

9. The method of Claim 1, further comprising the step of treating a reformate to reduce carbon monoxide concentration.

10. The method of Claim 9, wherein the step of treating a reformate is at least one of the following processes selected from the group consisting of a water gas shift, preferential oxidation of carbon monoxide, preferential methanation of carbon monoxide with hydrogen on a catalyst, separation of hydrogen in a pressure swing absorption bed, separation of hydrogen in a temperature swing absorption bed, and separation of hydrogen by a hydrogen-selective membrane.

11. The method of Claim 9 wherein the step of treating a reformate comprises a water gas shift.

12. The method of Claim 9, wherein the step of treating a reformate consists essentially of at least one water gas shift and at least one preferential oxidation of carbon monoxide.

13. The method of Claim 1, further comprising the step of heating a reformer with the burner exhaust before driving the expander.

14. The method of Claim 1, further comprising the step of heating a reformer with the burner exhaust after driving the expander.

15. The method of Claim 4, wherein the air/steam mixture travels a path from the fuel cell to the burner and wherein water is present in the air/steam mixture in at least part of the path.

16. The method of Claim 15, further comprising the step of removing water from the air/steam mixture at a selected point in the path before injection of the mixture into the burner.

17. The method of Claim 1, wherein the expander is a turbine.

18. An integrated fuel generator/fuel cell system, the system comprising:
a fuel reformer;
a fuel cell coupled to the fuel reformer;
a cooling system for the fuel cell configured to produce heated water;
a source of pressurized air;
a mixer in which pressurized air from the source is used to evaporate the heated water thereby creating a pressurized air/steam mixture;
a burner in which the air/steam mixture is combusted with a fuel to create a steam-containing burner exhaust; and
an expander in which the burner exhaust expands, thereby creating mechanical energy which is captured to improve system efficiency.

19. The system of Claim 18, wherein the expander is a turbine.

20. The system of Claim 18, further comprising a burner exhaust conduit configured to permit heating of the fuel reformer by the burner exhaust and then to direct the exhaust through the expander.

21. The system of Claim 18, further comprising a burner exhaust conduit configured to permit heating of the fuel reformer after the exhaust passes through the expander.

22. The system of Claim 18, wherein the air/steam mixture further comprises water in at least a part of a path between the fuel cell and a point of injection into the burner.

23. The system of Claim 18, further comprising a carbon monoxide removal system.

24. The system of Claim 23, wherein the carbon monoxide removal system produces an output which comprises less than about 10 ppm of carbon monoxide on a time-averaged basis.

25. A method of increasing the efficiency of a fuel cell, the method comprising the steps of:

converting at least some waste heat of the fuel cell to a pressurized gas/steam mixture by evaporating heated cooling water into a pressurized oxygen-containing gas and passing the gas through the fuel cell as oxidant;

heating the gas/steam mixture;

passing the heated mixture through an expander; and,

recovering mechanical power from the expander.

26. The method of Claim 25, wherein the step of heating is provided by at least one of the sources selected from the group consisting of a combustion zone, exhaust of a combustion zone, a fuel reformer; and a carbon monoxide removal system.

27. The method of Claim 25, wherein the expander is a turbine.

28. A method for generating power from fuel cell waste heat comprising the steps of:

evaporating water into pressurized air using waste heat from a fuel cell to create a pressurized air/steam mixture;

reacting the air/steam mixture in a burner to produce a steam-containing exhaust; and,

driving an expander with the steam-containing exhaust to produce mechanical energy.

29. The method of Claim 28, wherein the steam-containing exhaust is a heat source for a fuel reformer.

30. The method of Claim 29, wherein the fuel reformer conducts at least one reaction selected from the group consisting of steam reforming, partial oxidation and autothermal reforming.

31. The method of Claim 30, wherein the fuel reformer reaction comprises steam reforming.

32. The method of Claim 28, further comprising the step of treating a reformate to reduce carbon monoxide concentration.

33. The method of Claim 32, wherein the step of treating a reformate is at least one of the reactions selected from the group consisting of a water gas shift, preferential oxidation of carbon monoxide, preferential methanation of carbon monoxide with hydrogen on a catalyst, separation of hydrogen in a pressure swing absorption bed, separation of hydrogen in a temperature swing absorption bed, and separation of hydrogen by a hydrogen-selective membrane.

34. The method of Claim 32, wherein the step of treating a reformate comprises a water gas shift.

35. The method of Claim 32, wherein the step of treating a reformate consists essentially of at least one water gas shift and at least one preferential oxidation of carbon monoxide.

36. The method of Claim 28, further comprising the step of heating a reformer with the burner exhaust before driving the expander.

37. The method of Claim 28, further comprising the step of heating a reformer with the burner exhaust after driving the expander.

38. The method of Claim 28, further comprising the step of preheating the air/steam mixture by heat exchange with the steam-containing exhaust before reacting the air/steam mixture.

39. The method of Claim 28, further comprising the step of using at least some of the air/steam mixture as a humidified oxidant of a fuel cell before evaporating water into pressurized air.

40. The method of Claim 28, further comprising the step of injecting additional water into the air/steam mixture.

41. The method of Claim 40, wherein the step of injecting additional water occurs after the mixture has emerged from the fuel cell.

42. The method of Claim 40, wherein the air/steam mixture travels a path from the fuel cell to the burner and wherein water is present in the air/steam mixture in at least part of the path.

43. The method of Claim 42, further comprising the step of removing water from the air/steam mixture at a selected point in the path before injection of the mixture into the burner.

44. The method of Claim 28, wherein the expander is a turbine.

45. An integrated fuel generator/fuel cell system, the system comprising:

a fuel cell having a cathode and an anode;

a source of pressurized air coupled to the cathode of the fuel cell;

a fuel reformer coupled to the fuel cell;

a mixer in which pressurized air from the source is used to evaporate heated water thereby creating a pressurized air/steam mixture used as a fuel cell oxidant;

a burner in which the air/steam mixture is combusted with a fuel to create a steam-containing burner exhaust gas; and

an expander in which the burner exhaust gas expands, thereby creating mechanical energy.

46. The system of Claim 45, further comprising at least one heat exchanger to heat the air/steam mixture;

47. The system of Claim 46, wherein at least one heat exchanger is located within the fuel reformer.

48. The system of Claim 47, further comprising a radiator for cooling the fuel cell coolant wherein the radiator is configured to a size smaller than a size required to otherwise cool the coolant if a portion was not being used to humidify the cathode of the fuel cell.

49. The system of Claim 45, wherein the mixer comprises a humidifier.

50. The system of Claim 45, wherein the heated water is supplied by a fuel cell coolant.

51. The system of Claim 45, wherein the expander is a turbine.

52. The system of Claim 45, further comprising a burner exhaust conduit configured to permit heating of the fuel reformer by the burner exhaust and then to direct the exhaust through the expander.

53. The system of Claim 45, further comprising a burner exhaust conduit configured to permit heating of the fuel reformer after the exhaust passes through the expander.

54. The system of Claim 45, wherein the air/steam mixture further comprises water in at least a part of a path between the fuel cell and a point of injection into the burner.

55. The system of Claim 45, further comprising a carbon monoxide removal system.

56. The system of Claim 55, wherein the carbon monoxide removal system produces an output which comprises less than about 10 ppm of carbon monoxide on a time-averaged basis.

57. The method of claim 1, further comprising the use of the heat exchanger that cools the exhaust after it leaves the expander as a preheater for at least one of the feeds for the burner, thereby recuperating the turbine exhaust.

58. The method of claim 25, further comprising the use of the heat exchanger that cools the exhaust after it leaves the expander as a preheater for at least one of the feeds for the burner, thereby recuperating the turbine exhaust.

59. The method of claim 28, further comprising the use of the heat exchanger that cools the exhaust after it leaves the expander as a preheater for at least one of the feeds for the burner, thereby recuperating the turbine exhaust.

60. The system of claim 18, further comprising the provision of a heat exchanger that cools exhaust from the expander and heats at least one of the feeds for the burner, thereby recuperating the turbine exhaust.